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A Modeling Analysis Program for the JPL Table Mountain Io Sodium Cloud Data

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16. Abstract

The necessary personnel and software base was established this quarter at the Multimission Image Processing Laboratory (MIPL) at JPL to accomplish the data processing requirements of this project. Conversion of software required in reformatting the raw Io sodium cloud data was completed and data processing activities were initiated. Slit spectra data acquired by the JPL Table Mountain Io sodium cloud observing program were reviewed and their scientific value assessed. In preparation for modeling activities to begin next quarter, the lifetime description for sodium atoms in the Io sodium cloud model was improved by incorporating the most recently available temperatures and densities for ions and electrons in the plasma torus.

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I. Summary of Research Performed in the Third Quarter

Research activities in the third quarter have been focused upon (1) organization and initiation of data processing activities at MIPL, (2) review of the slit spectra data acquired by the JPL Table Mountain Io Sodium Cloud Observing Program, and (3) improvement of the model description of the lifetime of sodium atoms in the plasma torus in preparation for modeling activities next quarter.

1. Organization and Initiation of Data Processing at MIPL

A significant amount of effort was expended this quarter in establishing the necessary personnel and software base at the Multimission Image Processing Laboratory (MIPL) of JPL to accomplish the data processing requirements of this project. This base has been successfully established, and initiation of data processing for this project began in mid February. This date represents a delay of about one and a half months in our expected date for beginning data processing, but was unavoidable because of the recent major reorganization of the MIPL facility which entailed their old IBM 360 computer being replaced by two new VAX 11/780 computers and all data processing software being appropriately converted.

An excellent personnel base has been established at MIPL for the data processing needs of this project. Susan K. LaVoie, recently promoted to group supervisor at MIPL, is the key staff person responsible for overseeing this data processing. Additional senior data processing expertise will be provided by Glenn W. Garneau. Both G. Garneau and S. LaVoie have made significant contributions to past processing of the Io sodium cloud data at JPL (see Goldberg, Garneau, and LaVoie, 1984) and hence are very well suited for this project. In addition to G. Garneau and S. LaVoie, less senior MIPL staff personnel will also be assigned to support this project as required. To insure maximum science returns in the data processing activities, all MIPL staff personnel associated with this project will work together with and under the direct supervision of Bruce A. Goldberg of JPL.

A summary of the Io sodium cloud data processing to be performed by MIPL is given in Table 1 and is divided into four main steps. The first of these four steps has been accomplished in the third quarter. The conversion of the software programs, required specifically for reformatting the Io sodium cloud data, was performed by MIPL without cost to this project. This conversion has

removed the primary bottleneck that has up to this point prevented any of the subsequent data processing steps from being performed. The second step, that of refining the procedures for removing various image background signals, requires the joint involvement of senior MIPL staff and B. Goldberg. This second step was initiated in mid February. These refinement procedures are required to improve early developed techniques so as to display more accurately the true nature of the spatial morphology of the image data for modeling studies. Refinement of these procedures is a prerequisite for performing the third step of data processing. The third step, that of processing specified images, will be accomplished over a longer period of time in response to various modeling studies. The fourth step, that of processing single slit data, is required for calibration of the image data and also for stability studies. This will also be accomplished over a longer period of time. Both the third and fourth steps may be accomplished with the participation of experienced but less senior MIPL personnel working together with B. Goldberg.

2. Review of Slit Spectra Data

In addition to Region B/C image data, which were reviewed in the first two quarterly progress reports of this project, significant amounts of slit spectra data were also acquired in the 1974-1981 time period by the JPL Table Mountain Io sodium cloud observing program. The number of yearly measurements for both single slit (centered on Io) and multislit (two slits, nine arc seconds east and west of Io) observations acquired by this program are summarized in Table 2.

Single slit data obtained in 1974 and 1975 have already been published as noted in Table 2. These data were used to confirm resonance scattering as the sodium D-line excitation mechanism and to first document the east-west intensity asymmetry of the sodium cloud. Single-slit data obtained in 1976-1979 and also in 1981, which have not yet been fully processed, provide in addition a spatial resolution along the slit length (not a slit averaged value as in the 1974 and 1975 data). This one-dimensional resolution will provide a more accurate assessment of the slit-averaged intensity, since the continuum light of Io's disk that is truncated by the narrow slit width under normal seeing conditions can more accurately be estimated in this case than in the case of the earlier 1974-1975 data. The single-slit data in the 1976-1981

time period will be valuable (1) as an absolute intensity calibration for the 1976-1981 image data, (2) as a means of expanding and extending the earlier analysis of the 1974 and 1975 data (Bergstralh et al., 1975, 1977), and (3) as a base for studying the stability/variability of the Io sodium cloud (and ulitmately the Io plasma torus) over the 1974-1981 time period.

The dates and times and the Io phase angle and Io system III magnetic longitude ranges associated with the single-slit spectra of 1976-1979 and 1981 are summarized in Table 3 and Table 4 respectively. Spectral data from 1976-1979, having exposure times between 30 and 60 minutes, were acquired at most three times per evening and were clustered with several nights scheduled per month. Collectively, this provides information for the brightness of the sodium cloud from a month to a several-year time scale. Spectral data for 1981, having exposure times of only a few minutes, were acquired only over six nights, but were obtained with many more observations per night. The 1981 data thus provide information for the brightness of the sodium cloud over a day to a month time scale and in this way are both complementary and overlapping with the 1976-1979 data.

Only a small number of multislit observations were acquired in the observing program as summarized in Table 2. These observations were used primarily, in conjunction with early image data, to provide a numerical measure of the spatial morphology of the forward cloud. This was accomplished by forming a ratio of the intensity of the cloud in one slit located nine arc seconds to the west of Io to the intensity of the cloud in the other slit located nine arc seconds east of Io. This information has been recently reported by Goldberg, Garneau and LaVoie (1984) and was earlier used together with image data to first document the east-west orbital asymmetry in the Io sodium cloud (Goldberg et al., 1978). For completeness, the dates and times and the range of Io phase angles and Io system III magnetic longitudes covered by the multislit data are summarized in Table 5.

3. Lifetime for Sodium Atoms in the Plasma Torus

The lifetime description adopted for sodium atoms in the Io sodium cloud model has been improved this past quarter. Improvements have been made in the electron temperature and density by incorporating unpublished results obtained from new analyses of both the Voyager 1 PLS electron data (Sittler, 1984) and ion data (Bagenal, 1984). Corrections for a hotter ion temperature as

discussed by Bagenal et al. (1984) as well as unpublished ion abundances (Shemansky, 1984) were also used in determining the distribution of electrons along magnetic field lines above and below the centrifugal equator of the plasma torus.

This new lifetime for sodium, assuming longitudinal symmetry in the plasma torus, is shown in Figure 1. Inside of a radial distance of 8 R_J, the new lifetime is similar to earlier derived values in magnitude and structure. The new lifetime values on the centrifugal equator are, however, slightly larger and fall off slightly less rapidly with displacement from the equator than the old values. This occurs because of the lower electron temperatures between 6 and 8 R_J and the higher ion temperatures (everywhere) adopted in the new torus description. Outside of a radial distance of about 8 R_J, the new lifetime in Figure 1 exhibits an extension both radially and vertically that was not as pronounced in the older lifetime descriptions. This enhanced extension results from the higher ion temperature and also from a higher electron density and electron temperature that now occurs in the new description outside of about 8 R_J. Further refinements are expected in the sodium lifetime when new ion abundance information is available from the reanalysis of Voyager UVS data using a new improved atomic data set for oxygen and sulfur (Shemansky, 1985).

II. Program for the Fourth Quarter

Emphasis in the fourth quarter will be placed upon (1) implementation and assessment of the background signal removal procedures for image data (step II of Table 1), (2) initiation of image data processing (step III of Table 1) and single-slit data processing (step IV of Table 1), and (3) preliminary modeling of selected images that have undergone proper background removal and calibration. To facilitate these goals, W. Smyth will visit B. Goldberg at JPL for a week in late March.

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Table 1

Summary of Io Sodium Cloud Data Processing to be Performed by MIPL

I. Provide Access to Image Data and Single Slit Data in Raw Form
   (a) Convert TTRAN for VAX 11/780 to reformat data tapes
   (b) Convert VLOGSIP for VAX 11/780 to format data for VICAR programs
   (c) Collect all tapes containing image and slit data

II. Refine Procedure for Removing Various Image Background Signals
   (a) Provide VICAR programs (programs to filter, interpolate, plot, contour, remove part of frames, provide registration of parts of frames, subtract frames, normalize frames, rotate frames)
   (b) Remove Io spectrum from image (most difficult task)
      (1) locate and align wavelength of absorption feature in the frame
      (2) use spectrum from another satellite to model and subtract off absorption feature
   (c) Remove Jupiter background (relatively straightforward)
   (d) Define and remove optimally the background read-out (photon) noise level of each frame (i.e., average frames / use optimal low pass filter / use Fourier transform techniques)

III. Process Specified Images for Removal of Background Signals

IV. Process Single Slit Data for Calibration Purposes
   (a) Instrumental calibration
   (b) Removal of sky background
   (c) Produce integrated intensity profile

Table 2

Summary of Io Sodium Cloud Slit Spectra

	Single Slit Data			Multislit Data	
Year	Number of Measurements	Slit Intensity	Published Reference	Number of Measurements	Published Reference
1974	64	averaged	1,2	-	-
1975	8	averaged	2	-	-
1976	11	1-D	-	4	3
1977	7	1-D	-	4	3
1978	4	1-D	-	1	3
1979	9	1-D	-	-	-
1980	-	-	-	-	-
1981	56	1-D	-	-	-

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Table 3

1976-1979 Io Sodium Cloud Single Slit Spectra

	Date (UT)	UT Start	Io Phase	Io Sys III Mag. Longitude	UT End	Io Phase	Io Sys III Mag. Longitude
1976	29 November	7:28	17.1	276.5	8:28	25.5	304.3
	3 December	1:47	63.4	266.5	2:47	71.9	294.3
	3 December	9:47	131.8	128.3	10:47	140.3	156.1
	4 December	1:35	265.8	207.4	2:35	274.3	235.3
	4 December	2:42	275.3	238.5	3:42	283.7	266.4
	10 December	1:38	47.3	251.6	2:38	55.8	279.3
	10 December	2:40	56.1	280.2	3:40	64.6	308.0
	16 December	2:39	198.3	321.1	3:09	202.5	335.0
	25 December	3:11	234.7	219.1	4:11	243.1	247.0
	25 December	8:35	280.2	9.5	9:05	284.4	23.5
	25 December	9:13	285.5	27.2	9:43	289.7	41.1
1977	19 February	5:28	127.4	193.9	5:58	131.6	207.8
	5 October	12:30	99.4	197.6	13:10	105.1	216.2
	13 October	8:25	253.3	20.1	9:25	261.8	47.9
	5 December	11:46	269.9	188.9	12:46	278.4	216.8
	6 December	10:58	105.9	114.6	11:58	114.5	142.3
	13 December	8:42	72.0	41.1	9:42	80.5	68.9
	14 December	5:30	249.4	258.3	6:30	257.8	286.1
1978	22 January	3:46	255.3	304.5	4:16	259.5	318.4
	22 February	3:34	82.1	96.5	4:04	86.3	110.4
	15 December	12:40	230.3	155.6	13:40	238.8	183.3
	16 December	6:38	22.5	295.1	7:38	30.9	323.0
1979	26 February	5:36	273.6	53.6	6:06	277.8	67.5
	4 March	2:48	30.3	18.6	3:48	38.8	46.4
	4 March	8:44	80.6	183.6	9:44	89.1	211.4
	5 March	2:20	230.7	311.8	3:05	237.1	332.7
	5 March	9:24	290.6	148.3	10:09	296.9	169.2
	6 March	6:37	109.8	18.6	7:07	114.1	32.5
	7 March	3:41	289.2	243.4	4:26	295.5	264.3
	12 March	3:39	226.6	337.4	4:24	233.0	358.3
	12 March	7:09	256.3	74.7	7:54	262.6	95.5

Table 4

1981 Io Sodium Cloud Single Slit Spectra

Date (UT)	UT Start	Io Phase	Io Sys III Mag. Longitude	UT End	Io Phase	Io Sys III Mag. Longitude	Number of Measurements
25 March	6:11	17.9	251.5	6:29	20.4	259.8	4
25 March	9:05	42.4	332.2	9:13	43.5	335.9	2
25 March	9:23	44.9	340.6	9:42	47.6	349.4	4
25 March	10:31	54.4	12.1	10:36	55.1	14.5	2
5 April	4:41	84.4	347.8	5:09	88.4	0.8	7(slit E-W)
5 April	9:04	121.4	109.8	10:03	129.7	137.2	17
6 April	4:03	283.0	276.8	4:26	286.3	287.5	3
6 April	8:07	317.7	29.7	8:37	322.0	43.6	5
11 April	3:49	218.6	6.0	4:27	224.0	23.5	5
27 April	4:00	237.7	243.2	4:17	240.2	251.0	3
4 June	6:20	70.5	94.3	6:37	72.9	102.2	4

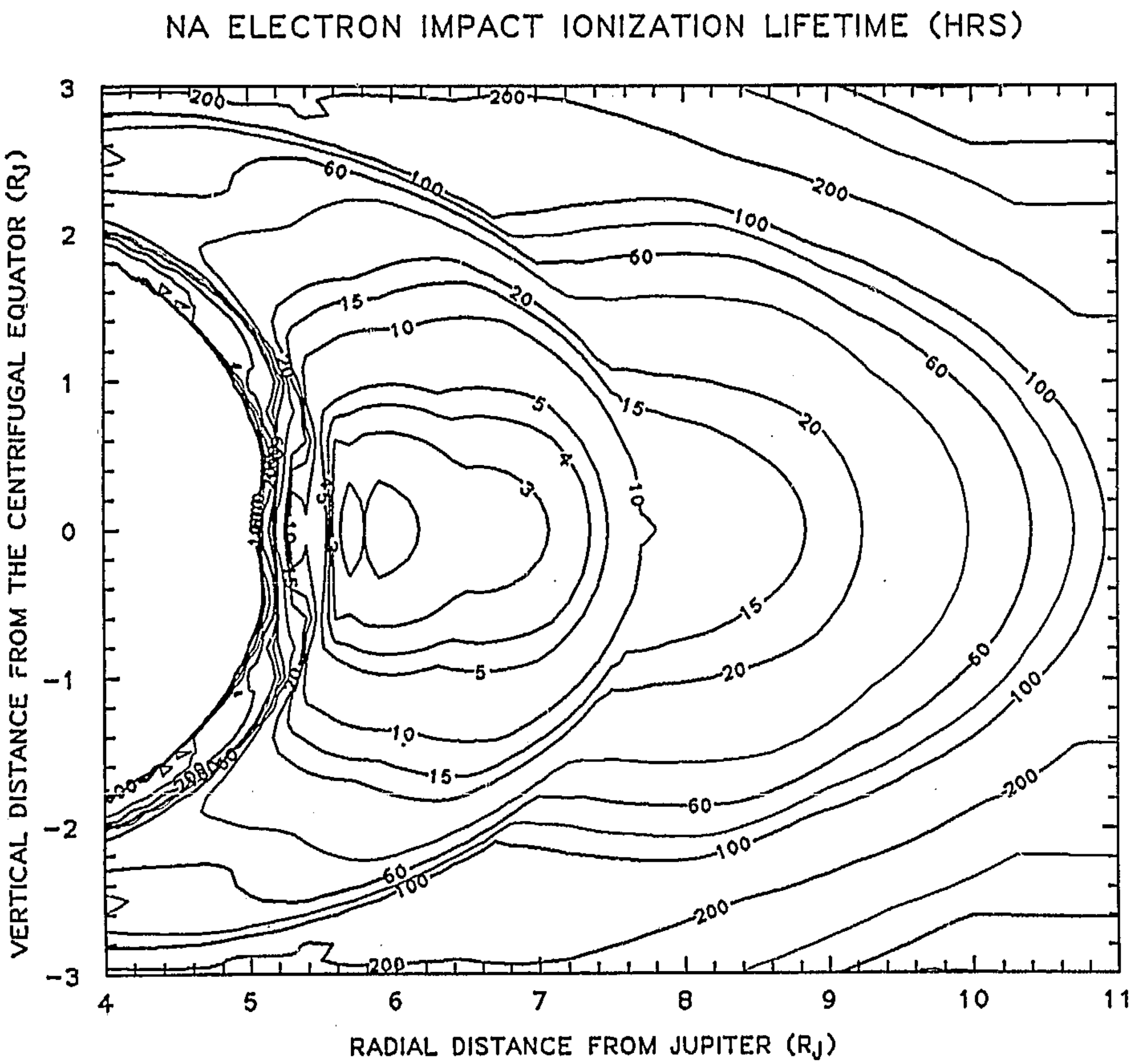
Table 5

1976-1978 Io Sodium Cloud Multislit Spectra

	Date (UT)	UT Start	Io Phase	Io Sys III Mag. Longitude	UT End	Io Phase	Io Sys III Mag. Longitude
1976	30 November	7:40	223.3	228.2	10:40	248.6	311.6
	1 December	4:41	40.7	93.1	7:41	66.2	176.4
	3 December	6:44	105.7	43.8	9:41	131.3	127.0
	25 December	5:20	252.8	279.0	7:50	273.9	348.6
1977	18 January	1:55	67.7	352.2	4:55	93.3	75.4
	25 January	2:12	54.2	349.1	5:12	79.8	72.3
	8 February	2:53	27.7	346.0	4:23	40.5	27.6
	27 February	2:36	289.1	51.0	5:21	312.3	127.5
1978	22 January	1:41	237.7	246.5	3:41	254.6	302.2

Figure Captions

Figure 1. Lifetime of Sodium Atoms in the Io Plasma Torus. The improved lifetime description is calculated by using the most recently available properties for the ions and electrons deduced from Voyager 1 encounter data as discussed in the text.



NA ELECTRON IMPACT IONIZATION LIFETIME (HRS)
VERTICAL DISTANCE FROM THE CENTRIFUGAL EQUATOR (R_J)
RADIAL DISTANCE FROM JUPITER (R_J)
3
2
1
0
−1
−2
−3
4
5
6
7
8
9
10
11
200
100
60
20
15
10
5
4
3

Figure 1